Brain-Computer Interface Related Work with Around-the-Ear EEG Recordings

Chris Winnard; supervisors: Dr Marcus Pearce, Prof P. Kidmose, Prof K. Mikkelsen

Background

- Auditory attention decoding (AAD): using electroencephalography (EEG) to determine what a listener focuses on (Geirnaert *et al.*, 2021).
- This may have uses in communicative BCIs ("attend to the keyboard for yes, vibraphone for no", etc).
- Backwards encoding: reconstructing the audio from the EEG, and comparing the reconstruction to the original stimuli: **attended audio should have more faithful reconstructions!**
- There is currently a focus on studying mobile EEG, which is easy to set up and can be worn outside the lab, including EEG earpieces (earEEG).

Images: Hope (https://flic.kr/p/doVQPX); Bleichner and Debener (https://doi.org/10.3389/fnhum.2017.00163).

Research Problem

Two main practical issues:

1. Current developmental systems require attending to stimuli such as tones- can quickly become fatiguing.
2. EEG setup takes time/expertise, and the wearer is constrained to one spot.

Both of these are detrimental to long-term or regular use.

Solutions:

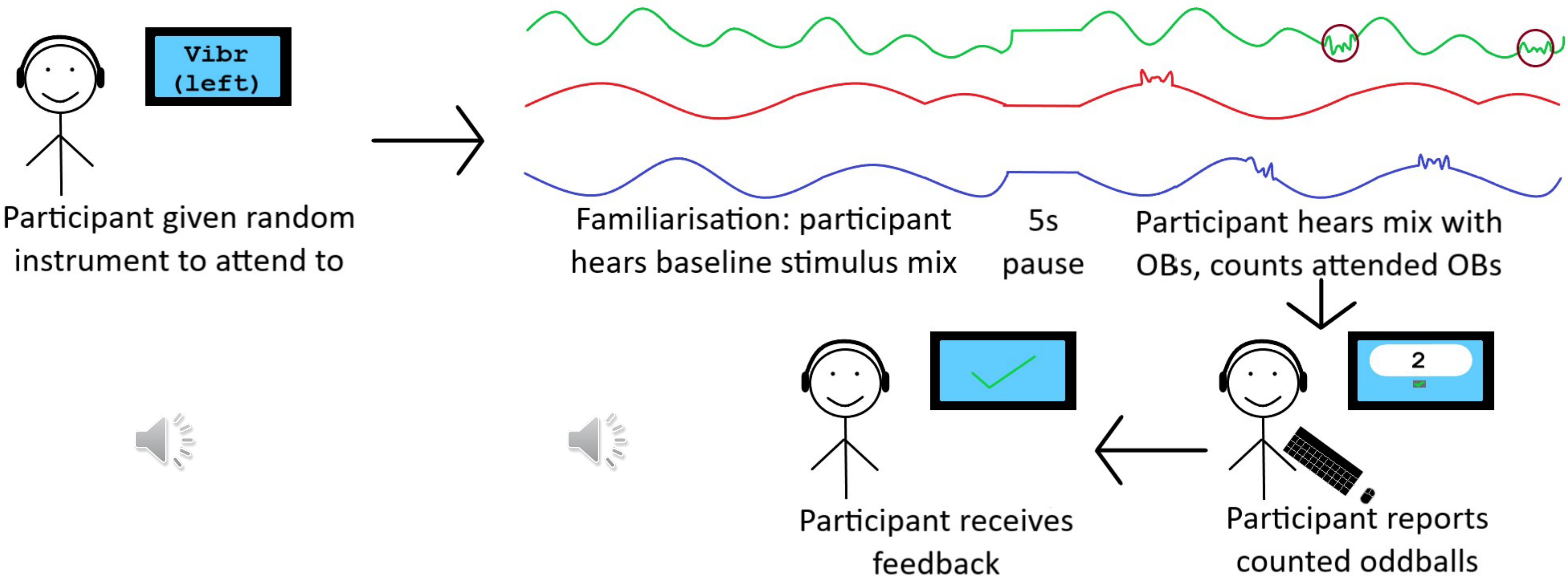
1. To prevent participant fatigue, use pleasant stimuli- music? Better yet, have an interactive element- a listening game?
2. For practicality, use mobile EEG.

Can earEEG and a musical task be combined for a user-friendly BCI?

Experiment

- Both scalp and around-the-ear EEG used to record data from 32 participants.
- Stimuli: 30s excerpts, instruments chosen to be equally salient/'attention-grabbing' based on previous research (An *et al*., 2021): participant would hear vibraphone from left, harmonica from centre, keyboard from right.

Experiment


Vibr (left)
Participant given random instrument to attend to
Familiarisation: participant hears baseline stimulus mix
5s pause
Participant hears mix with OBs, counts attended OBs
2
Participant reports counted oddballs
Participant receives feedback

Analysis

- For now just focusing on binary classification (e.g, vibraphone/piano).
- Participants picked task up quickly, so decided to use practice trials for training/testing.
- Supplementing training data with data from other parts of the same experimental session.

Analysis

- EEG/music preprocessed (filtering, etc).
- For each instrument:
  - Train a model with the attended trials of the **other** instrument (a "comparison model").
  - For each trial where the current instrument is attended (a test trial):
    - Train a model with all other trials.
    - Use the comparison model and the model just trained to reconstruct their respective instruments' stimuli for the trial, from the EEG data.
    - Whichever instrument's reconstruction is better (measured by linear correlation with the original) is assumed to be the attended instrument.

Results and Reflection

- Participants were quick to grasp the oddball task (average success rate of 86%).
- Additionally, participants often reported enjoying the task → indicates **viability for long-term use for a BCI**.
- So far max decoding accuracy of 56% achieved, for vibraphone/piano class. with scalp EEG.
- May be better if more data collected per participant, or if stimuli were more homogeneous (wide range of styles/techniques used for each instrument- may be confusing models).
- Currently working on retuning preprocessing methods to improve SNR, and sourcing training data from elsewhere.
- Possible experiment improvements: more trials per participant, more homogenous stimuli for each instrument.

AI + MUSIC

Thanks for listening.

References

[1] S. Geirnaert *et al*. (2021). 'Electroencephalography-Based Auditory Attention Decoding: Toward Neurosteered Hearing Devices', *IEEE Signal Process. Mag*. 38(4), pp. 89 – 102. DOI: 10.1109/MSP.2021.3075932
[2] An, W.W. *et al.* (2021). 'Decoding Music Attention from "EEG Headphones": A User-Friendly Auditory Brain-Computer Interface', *2021 – ICASSP*. pp. 985-988. DOI: 10.1109/ICASSP39728.2021.9414492